VOLUME I
PERFORMANCE PHASE

CHAPTER 1
INTRODUCTION TO AIRCRAFT PERFORMANCE TESTING

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1.1 INTRODUCTION

Aircraft performance can be defined as the ability of an aircraft to climb, accelerate, or maneuver in order to successfully accomplish its mission. Obviously, expected performance specifications must be an integral part of the design process of an aircraft. Given certain performance expectations by the customer, the designer must make decisions regarding wing loading, power plant selection, airfoil selection, planform configuration, and many other considerations. All of these help to tailor the design to give the aircraft the desired performance characteristics.

It is also certain that actual performance characteristics will not always be the same as those predicted by the designer. Herein lies the need for performance flight testing. Performance flight testing is defined as the process of determining aircraft performance characteristics, or in a more modern sense, evaluation of the energy gaining and losing capability of the aircraft.

Determination of aircraft performance is dependent upon our knowledge of fundamentals in several different scientific disciplines. In order to predict or measure an aircraft's performance, we must be able to estimate the aerodynamic forces involved. This requires knowledge of the properties and behavior of the fluid medium in which we operate, i.e., the earth's atmosphere. Therefore, we must study atmospheric science, fluid dynamics, thermodynamics, and aerodynamics. Performance prediction or measurement requires knowledge of the aircraft propulsion system. Hence, we must be familiar with the theory and operation of basic turbine and turbine variant engines, reciprocating internal-combustion engines, and propeller theory. We must also understand the basic measurements, instrumentation techniques, and equipment used to gather the data needed to determine an aircraft's performance.

Once we have a background in these various fields of study, we can begin to answer questions about the aircraft's predicted or actual performance such as:

How well can the aircraft accelerate or climb?
How far or how long will the aircraft fly on a load of fuel?
How much payload can the aircraft carry?
What length of runway is required for takeoff and landing?
What is the aircraft's maximum sustained turn rate?

We must determine the proper parameters to use in our analysis. For example, this is dependent upon the type of propulsion system the aircraft has. Reciprocating engines are normally rated in terms of power, and therefore certain characteristics of propeller driven aircraft are given in terms of power available and power required. Turbine engines are normally rated in terms of thrust, and therefore it is more logical to analyze performance characteristics in terms of thrust available and thrust required. Turboprops, turbofans, and rotary wings exhibit some characteristics of both types of power plants and must be analyzed accordingly.

Performance can be subdivided into steady state performance and dynamic performance. Steady state performance characteristics are normally determined by analysis of the basic thrust, weight, lift, and drag forces involved in an equilibrium or quasi-equilibrium condition, i.e., where the velocities and other flight path parameters are either constant or are changing so slowly that their rate of change can be neglected. For instance, steady-state top speed in level flight occurs at the high speed intersection of the thrust required versus thrust available curves. Quasi-steady state rate of climb or acceleration is dependent upon the excess of power available over power required, which varies slowly during the maneuver. In contrast, dynamic performance maneuvers, like a split-s, involve rapidly changing flight parameters. In dynamic performance analysis we must consider accelerations along and normal to the flight path in addition to the basic parameters used to determine steady state performance characteristics.

Over the past 20 years, more and more aircraft performance testing has been dedicated to the validation of aerodynamic and propulsion system models for use in performance prediction routines. Aircraft aerodynamic models are relationships between lift, drag, and angle of attack. Propulsion system models predict engine thrust or power and fuel consumption rates. The development and verification of aircraft models reduces the amount of performance flight testing actually required. An understanding of the development, testing, and use of aerodynamic and propusion system models will be critical to any future aircraft performance test program.

Performance flight testing is conducted with several fundamental purposes in mind other than determining the actual performance characteristics of an aircraft. It is also used to:

1. Determine if the aircraft meets performance specifications, or hard performance requirements as specified in the user generated Statement of Need (SON).
2. Provide data for aircraft flight manuals to be used by operational aircrews.

3. Determine techniques and procedures to be used by operational aircrews to attain optimum aircraft performance.
4. Obtain research information to advance aeronautical science or to develop new flight test techniques.

Performance requirements originate with the aircraft user. Aircraft performance is the primary consideration in the sale of aircraft to either an individual owner, an airline, or to the military. An individual aircraft owner purchases an aircraft to meet specific air transportation performance needs in terms of range, takeoff distance, and cruise speed. For an airline, an aircraft must have the performance specified in the sales contact to be economically feasible as a revenue producing vehicle.

It must also satisfy minimum performance requirements of the Federal Aviation Administration to be certified as a passenger or cargo carrying aircraft. In the military, the using major air command specifies performance requirements for new aircraft in the form of a SON for an operational capability to perform some assigned mission. If a new aircraft development is undertaken, the contract often specifies performance guarantees which the aircraft must meet.

When a contractor proposes a design for a US military aircraft he is normally required to present performance data and guarantees in accordance with the format provided by MIL-C-5011A. This specification governs the definition and methods of presenting performance date.

Usually as part of the aircraft development contract, the contractor is required to provide complete estimates of aircraft performance in the format which is used in USAF Flight Manual performance data charts. MIL-M-7700B (USAF) specifies flight manual data presentation requirements for all types of aircraft.

As aircraft become more and more technologically sophisticated, it is almost certain that the future heralds the development of newer and better methods of aircraft performance prediction and determination. It is incumbent upon the experimental test pilot, navigator, and flight test engineer to be in the forefront of that development. Such expectations can be realized only if he or she possesses a working knowledge of the material contained within this volume.

The performance curriculum at the USAF Test Pilot School follows the sequence given below:
1. Performance data analysis methods and statistical mathematical techniques are introduced, and instrumentation principles are discussed.

2. Subsonic, supersonic, and hypersonic aerodynamics courses provide the fundamental aerodynamic concepts required for use throughout the remainder of the curriculum.
3. Theory and in-flight calibration of primary performance measuring systems and pitot-static systems are covered in detail.
4. Development and validation of aerodynamic and propulsion system models to predict and correct aircraft performance measurements are taught.
5. An energy concepts course provides the fundamental theory for use in steady and non-steady state testing such as accelerations, climbs, and turns.
6. Other courses develop the background theory and present techniques for testing takeoff and landing, cruise, and propulsion systems.

1.2 COURSE SUMMARY

Introduction to Aerodynamics
Compressible Aerodynamics
Hypersonic Aerodynamics
Pitot-Static Systems
Equations of Motion
Aerodynamic Modeling
Energy Concepts
Takeoff and Landing, Braking and Barrier Testing
Propulsion
Cruise

1.3 FLIGHT SUMMARY

For a flight summary, refer to the current Performance Phase Planning Guide.